# CONCRETE THROUGH THE AGES

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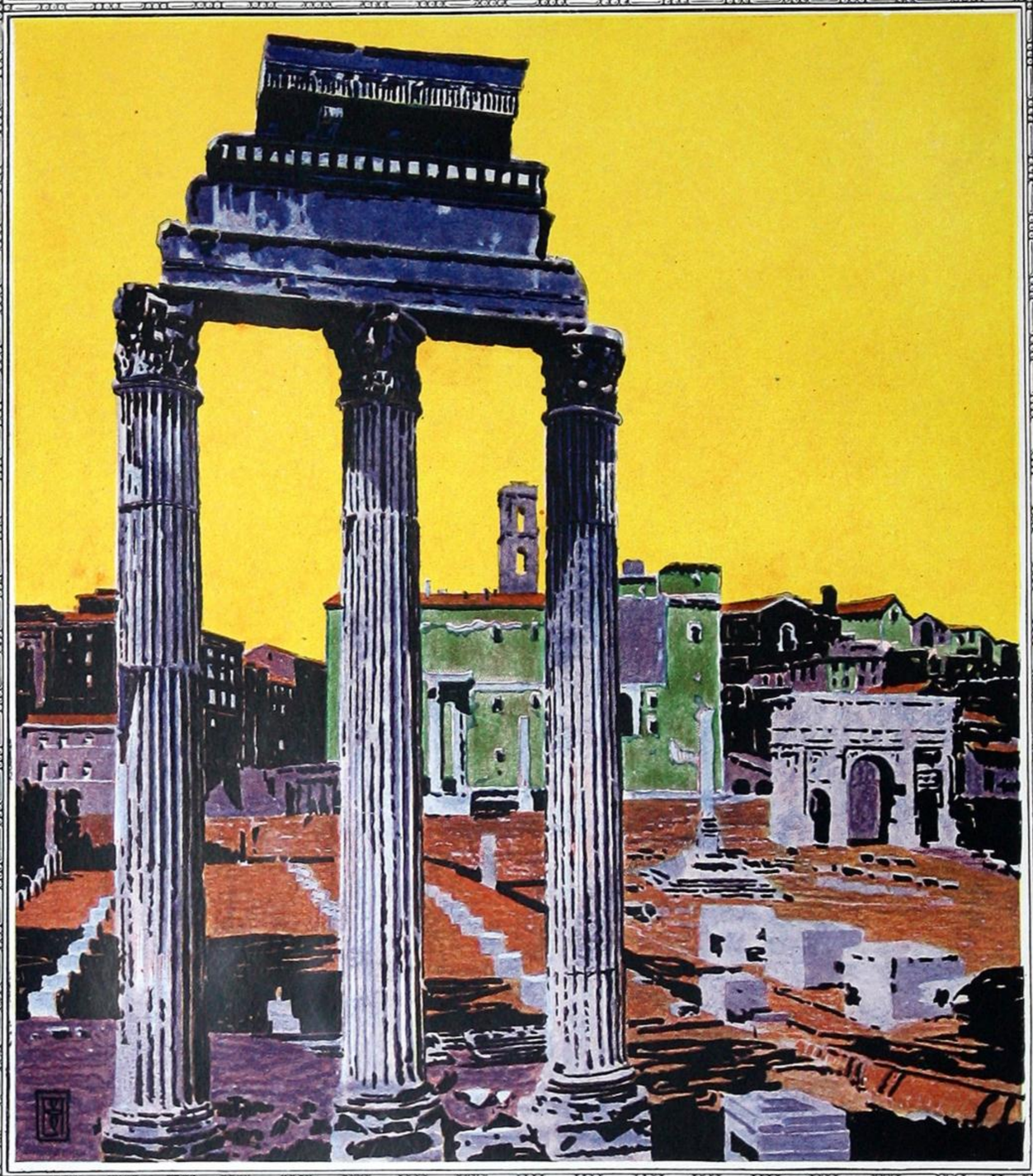
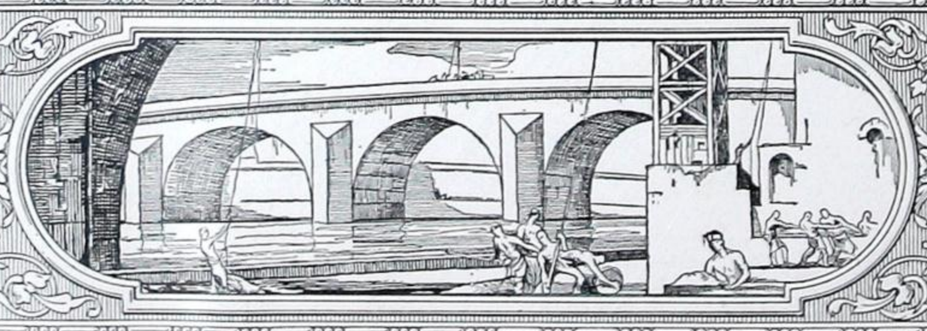


CONCRETE FOR PERMANENCE

# PENNSYLVANIA PORTLAND CEMENT



# Concrete Through the Ages

## Looking Backward Twenty Centuries on Concrete Construction

"Master Builders *of* Ancient Rome"

A Series of Six Color Drawings by

Birch Burdette Long

Pennsylvania Cement Company

New York Bath, Pa.

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J. A. Richards and Staff
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New York

# Concrete
# Through the Ages

A HUNDRED centuries ago man came down from his home in the trees to live in a mud hut; but through the slow stages of progress in building construction from sun-dried bricks, timber, and stone to the wonderful concrete work of the Roman Empire, and finally to modern steel-and-concrete construction, man has never gotten over the habit of high living. More than seven hundred feet above the roadway in the fifty-sixth story of the Woolworth Building, modern man has his habitation.

Ancient monumental architecture of stone construction originated with the Egyptians and reached its apogee centuries later in the Parthenon of the Greeks. During this period in history building construction was so exceedingly laborious as to seem an object in itself rather than to serve a purpose.

The first extensive use of concrete construction and its extraordinary development by the Romans from about the first century B. C., came in direct response to a demand for building construction as a means to an end. Practically all of the then-known world paid tribute to Rome. Conquest had been rapid. Newly-won provinces were restive. Triumphal arches, temples, theatres, aqueducts, bridges and roads were constructed on a vast scale as signs and symbols of Roman power and administrative energy. It was a "speeding

up" period in building construction unparalleled for twenty centuries until the introduction of present-day methods.

The prodigious strides in engineering and architecture made by the Romans were due primarily to their discoveries in concrete mixing. At the foot of Vesuvius were immense deposits of reddish sand or volcanic ash, called *pozzuolana*, which when added to lime mortar made hydraulic cement. This discovery gave to the Romans a concrete of extraordinary strength and permanence which hardened under water as well as in the air, and became the basis of their entire system of building.

In spite of the practical demonstration that Rome had given to the world, concrete gradually fell into disuse. French and English writers as late as the eighteenth century speak of the Roman method of mixing concrete as a lost secret, buried in the darkness of the Middle Ages.

After nineteen hundred years, hydraulic cement was rediscovered by an English engineer in building the Eddystone Lighthouse, and eighty years later another Englishman, Joseph Aspdin of Leeds, produced Portland Cement by burning and grinding limestone combined with clay. These discoveries, however, gave little impetus to concrete work until the introduction of railways and steam machinery for grinding cheapened the cost of manufacture and freight.

The greatest modern development of concrete has taken place in America, although Portland Cement which made it possible was patented by an Englishman, and the discovery of reinforced concrete is credited to a French gardener. The manufacture of Portland Cement has been brought to its highest perfection in this country, and our use of concrete ranges from a watering-trough on the farm to the Panama Canal.

# The Pantheon

## Rome

THE Roman system of building construction, from about the first century B. C., was based on the use of concrete. Primitive forms of arched construction with concrete are traced to the Chaldeans and Assyrians, in lands where clay was plentiful and stone comparatively rare; but the real development of the system stands to the credit of the engineers and architects of imperial Rome. Their massive walls, arches and vaults, were built of concrete faced with brick or stone, a method infinitely cheaper and more rapid than the laborious stone construction of the Greeks and Egyptians, and one which enabled them to utilize the unskilled labor of hordes of slaves and soldiers.

## The First Fire-proof Roofs

IT was this system "which first made possible the impressive architectural effect of vast and lofty interiors unencumbered by piers and columns. Of this grandeur and amplitude of internal effect the Pantheon at Rome is the noblest and greatest antique example." Almost perfectly preserved, as shown by the illustration on the following page, the Pantheon stands as a striking example of the permanence of concrete construction and the genius of the Roman builders.

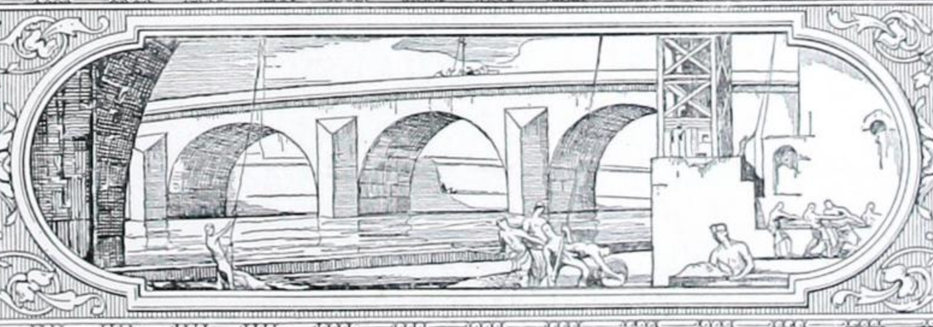
Inventive and boldly practical, these men of two thousand years ago, introduced many revolutionary and still valuable principles

in building construction. They originated the groined vault and dome, and the first fireproof roofs, other than stone, are found on the Pantheon and other Roman temples. Wooden roofs were used by the Greeks, and the ruins of their ancient buildings are open to the sky; and while the Egyptians built roofs of stone they were forced to obstruct their interiors with closely set columns, as in the Great Hall at Karnak where the broadest hall is about twenty feet wide and not over eighty feet high. Compare with this the spacious unobstructed interior of the Pantheon with its diameter of 142 feet and height of 140 feet to the summit of its paneled dome.

## Walls Twenty Feet Thick

THE Pantheon was built by Hadrian early in the Christian era. Its circular walls were filled with concrete faced with broad, flat bricks, and are twenty feet thick. The inside of the massive concrete dome is decorated with 140 panels and has a circular opening, or "eye," at the summit which admirably lights the interior. There is a curious contradiction between the construction and decoration of the dome. Although stucco was known, and had been used earlier for frescoes and other decorations, the paneled face of the dome interior was made of bricks. It is said that the engineers in charge feared to use plastic cement over so wide an expanse, but why they hesitated after successfully executing extraordinarily difficult construction on new and radical lines, is hard to conceive. But despite their mistakes, which were numerous, the Roman engineers were unquestionably the greatest of their times and many of their works rival the achievements of the twentieth century.


# CONCRETE FOR PERMANENCE
# PENNSYLVANIA PORTLAND CEMENT



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# The Pont du Gard

## Nimes

TO Caesar's terse message, "I came, I saw, I conquered," the Romans might well have added, "we improved." In the remotest colonies of the vast empire conquest was followed by constructive improvements on an enormous scale, including aqueducts, bridges, roads and other public works. Perhaps the most interesting from an engineering, as well as architectural, standpoint were the great aqueducts of which about one hundred are still in existence. The earliest were built of cut stone, but during the first century B. C. *concrete* was used, sometimes faced with brick.

The inventive Romans found that *pozzuolana*, a kind of sand from the foot of Vesuvius, gave hydraulic properties to their lime mortar. This discovery enabled them to successfully employ *concrete* for piers, harbors and aqueducts, and was the first step, so far as we know, toward pure hydraulic cement.

## Over Twenty-five Miles Long

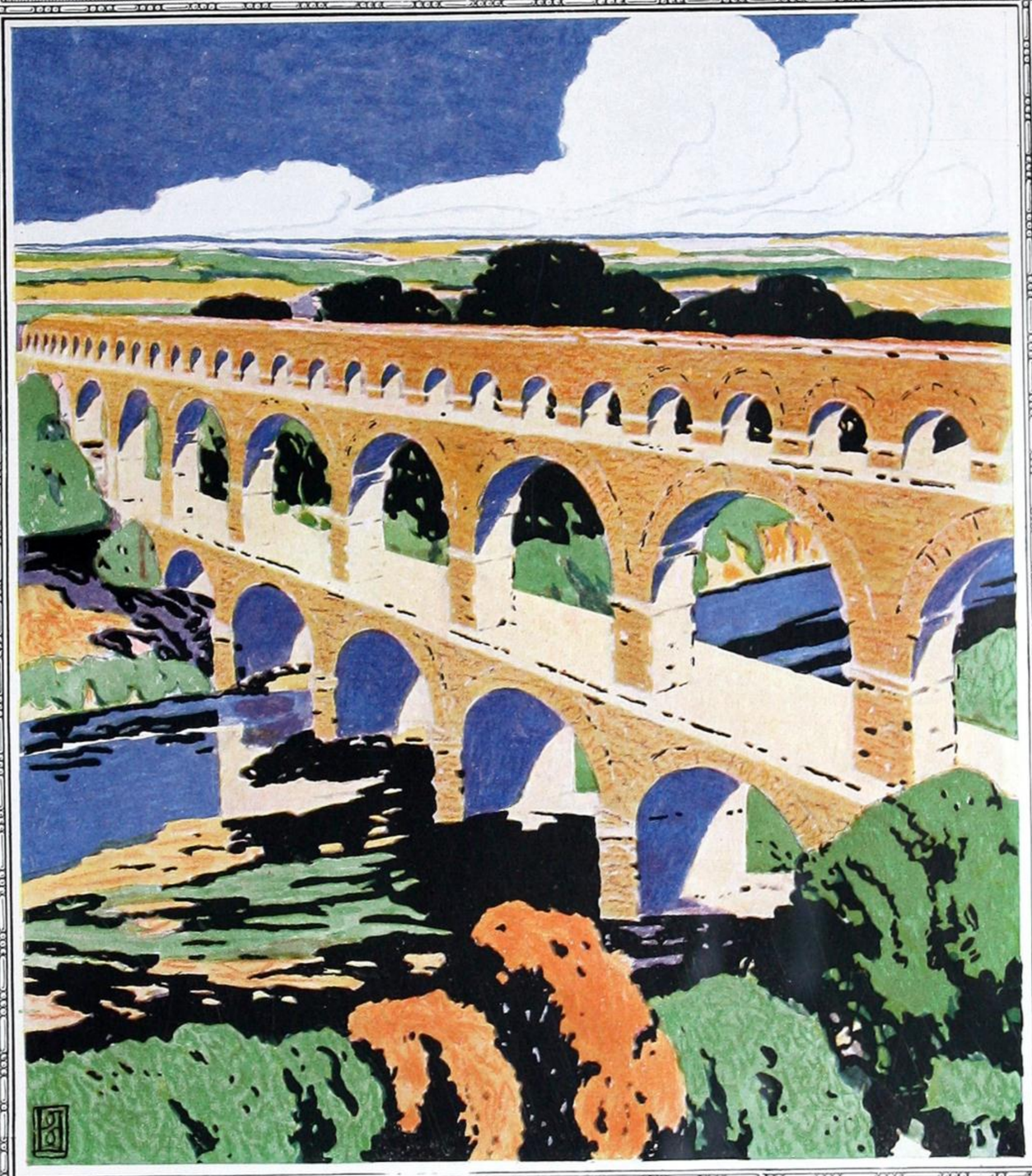
ONE of the largest and finest of the Roman aqueducts is the *Pont du Gard*, the subject of the illustration on page thirteen. This magnificent structure, nearly two thousand years old, spans the river Gardon at a short distance from Nimes, in Southern France, and was part of an aqueduct more than twenty-five miles long. "Few other Roman works anywhere rival this in grandeur and

impressiveness. Eight hundred and eighty feet long, one hundred and sixty feet high, it is composed of three tiers of arches of decreasing width, the whole constructed of massive blocks of stone. . . . Piled arch on arch this is, from a constructive and artistic point of view, one of the finest conceptions of Roman imperial architecture. Its immensity, its solidity, the constructive genius shown in it, and its grandeur, give us a vivid realization of what the character and abilities of its builders must have been."

## Made Water-tight by Concrete

THE water channel, about four feet wide and five feet deep, is partially obstructed by a thick lime deposit, which, where removed, reveals a deep layer of red-colored cement. In other aqueducts, still to be found in ancient Roman colonies, concrete played a more important part, but none afforded equal inspiration to our artist.

A modern historian has recently tried to prove an analogy between social conditions of contemporary America and those obtaining in Rome before the Fall. However that may be, we know the Romans were like us in their appreciation of the value of concrete construction and in their passion for time-saving methods.



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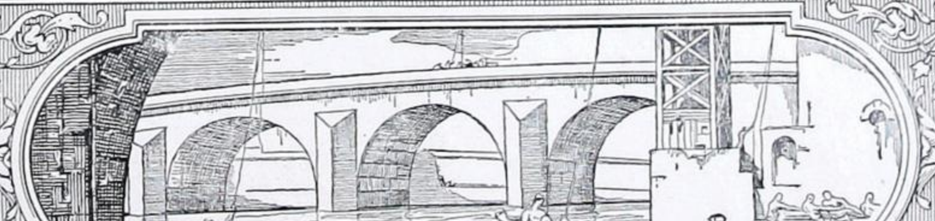

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# The Pons Fabricius

FORTY years after the completion of the contract the last guarantee-deposit was returned if the work proved satisfactory—so runs in substance the engraved inscription on the Pons Fabricius, an ancient bridge over the Tiber, which is the only one that remains intact after nearly two thousand years. Although the Imperial treasuries were opulent, it needed a long purse to be a contractor on public work in ancient Rome.

## The First Hydraulic Cement

THAT forty-year guarantee may have been the reason why the Romans "gave more attention to the selection of good materials and careful manipulation in making mortar than any other people." According to Pliny, "lime was not allowed to be used until it had been slaked for a period of three years." It was then mixed with sand, pulverized in a mortarium and made into cement. The Romans discovered that "pozzuolana," a kind of volcanic sand found at Pozzuoli, near the foot of Vesuvius, could be mixed with lime-cement and rubble to make a concrete which hardened under water. This discovery enabled them to successfully execute piers, harbors and aqueducts, and was the first step, so far as we know, toward pure hydraulic cement.

The Pons Fabricius, illustrated on the following page, has been known since the Middle Ages as the Ponte Quattiro Capi, from the four-headed Janus, guardian deity of gates, which decorates the east entrance. It has two arches, each with a span of approximately twenty-five metres, and its width is about fifteen metres. This bridge was constructed, or restored, by Lucius Fabricius in 62 B. C. and is mentioned by Horace as very attractive to suicides. At this period, arched construction with concrete, which was known by the Etruscans and originated with the Chaldeans and Assyrians, was highly developed by the Romans and used by them in temples, aqueducts and other construction. In fact, their system of building construction was based entirely on the use of concrete.

## Concrete Indispensable

THE innumerable building projects carried out by the Roman engineers and architects during the high tide of the Empire, would have been impossible without concrete construction. They operated over a vast conquered territory, practically all of the then-known world. Without railroads or machinery and with a minimum of skilled labor, they moved their armies of workmen from place to place, building with astonishing rapidity and achieving architectural effects of beauty and grandeur that are happily, in many cases, preserved to us through the permanence of concrete construction.

CONCRETE FOR PERMANENCE

# PENNSYLVANIA PORTLAND CEMENT

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# Via Appia

## Brindisi—Rome

"JULIUS CAESAR, Superintendent of Roads." It seems a humble office for so great a man to have held, but in ancient Rome it was one of great dignity. Triumphal arches were erected in honor of the great men who were active in establishing her marvelous system of roads, comprising in 200 B. C., about 50,000 miles, but the roads were magnificent monuments in themselves, both to their builders and, in many cases, to the enduring qualities of concrete construction.

"No other roads have ever been constructed so direct, so solid and so admirably adapted to their purposes as those built by the Romans. They ignored all obstacles and built in the most direct line practicable, making deep cuts and fills with apparently little regard for those features which we consider obstacles of sufficient magnitude to be avoided."

## Roman Road Construction

MOST of the Roman roads were built in four courses as follows: The Statumen, from 10 to 20 inches thick, formed of large stones laid flat on a compact bed of sand, and bonded together with mortar; the Rudus, about 8 inches thick, of rubble masonry; the Nucleus, about 10 inches thick, built of *Concrete;* and finally, the

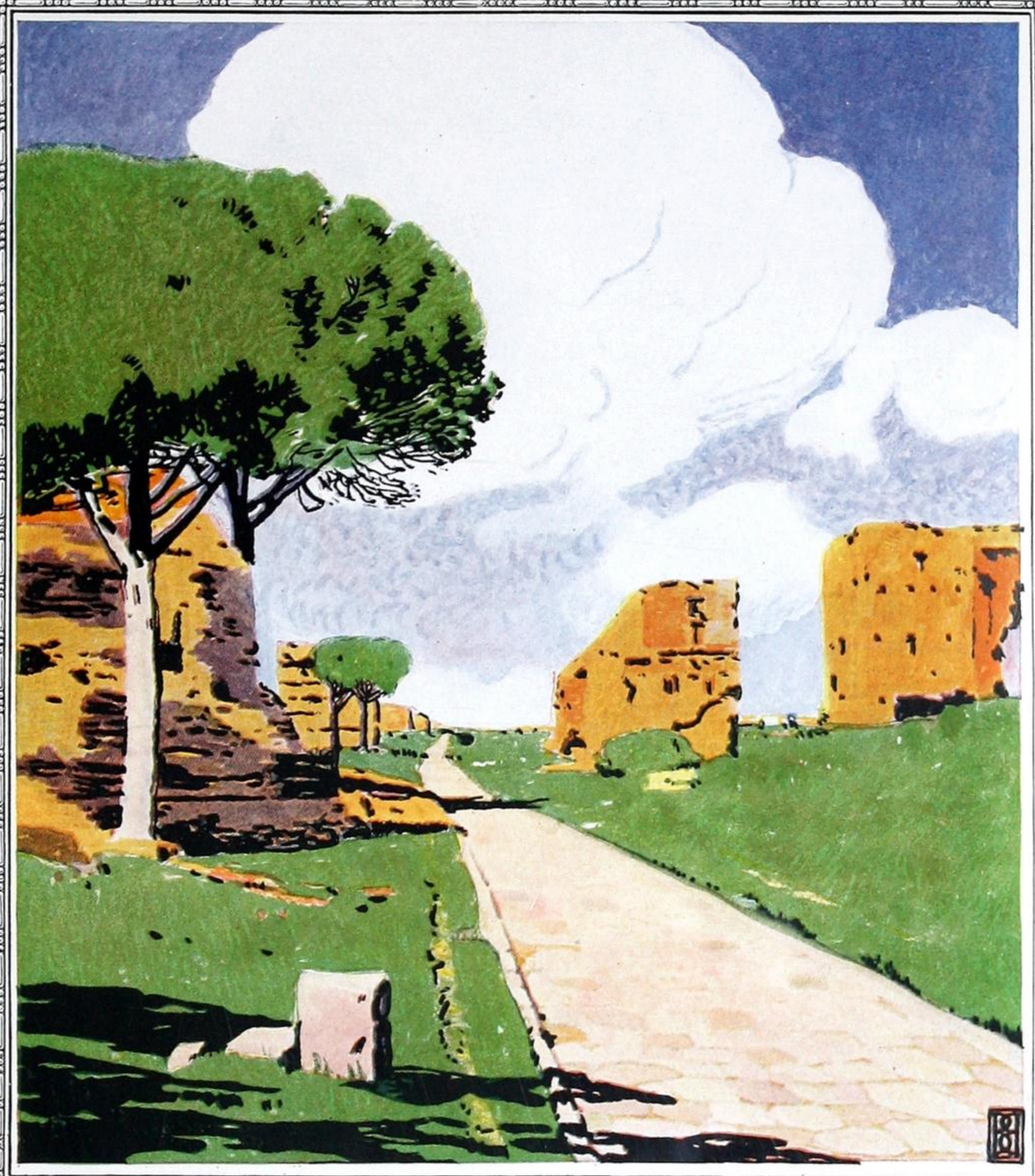
Summa Crusta, made of various hard materials bonded together with mortar. The latter layer was in many cases omitted in favor of large stones imbedded in the *Concrete* Nucleus. Think of building roads *four feet thick* for vehicular traffic such as chariots!

## The Appian Way

THE Appian Way, a section of which is illustrated on the following page, was begun in 311 B. C., and was the first paved road constructed by the Romans. Between Rome and Brindisi, for about 500 miles, it was surfaced with large flat stones from three to five feet square, set in mortar.

All roads led to Rome. Twenty-nine great highways were necessitated by the extensive movements of the troops throughout the Empire which comprised, in Trajan's reign, nearly all of Europe, parts of Asia and the northern part of Africa. After twenty centuries certain Roman roads are intact and in use to-day with only ordinary attention needed for maintenance.

The efficient use of concrete in road construction, no less than in great aqueducts, bridges and public buildings, gave almost indefinite endurance to the works of Roman architects and engineers. What we know of the Romans is largely due to these eloquent monuments. In the same way, the use of concrete to-day contributes to the permanence of the great achievements in construction by which the genius of our present civilization will be judged after centuries to come.



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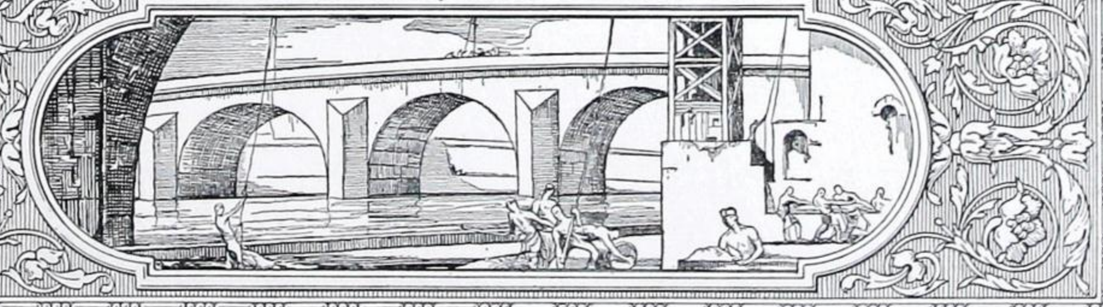


# The Amphitheatre at Pompeii

"WHAT'S new?" says the friend you meet on the street, and to be meticulously truthful, you are forced to fall back on an old bromide and reply, "There's nothing new under the sun."

Most people think of concrete construction as a comparatively recent development of the building art. And not so long ago stucco houses were termed an innovation. But it is a fact that before the Christian era the Romans used concrete and stucco as extensively, and nearly as efficiently, as we do to-day.

## The Stucco Houses of Pompeii

IN Pompeii, the summer city of Rome, we find the "house of Meleager" with the front covered with white stucco, imitating stone; also the Basilica, whose columns are coated with a fine-grained hard stucco.

Domestic architecture was not developed to any extent by the Romans because the warm climate permitted them to live and work and play in the open air; but their roads, aqueducts, temples and amphitheatres are achievements in concrete construction that compare in many cases with present day examples.

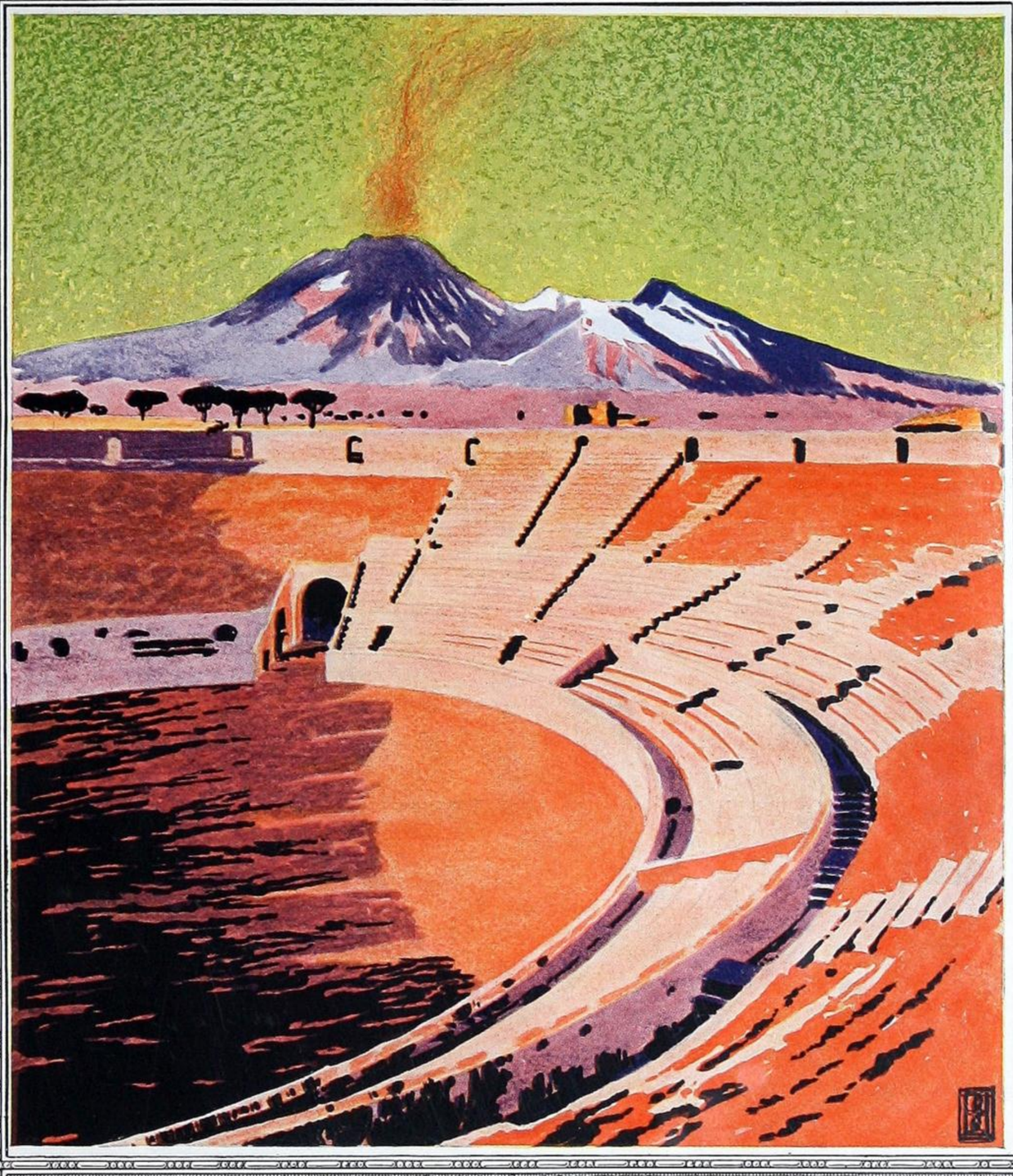
The huge Yale Bowl, with its seating capacity of 70,000, while more truly a concrete structure, is in many respects similar to the

old Roman amphitheatres. The resemblance will be noted, on referring to the illustration on the following page, of an amphitheatre near Pompeii, built about 75 B. C. This is the oldest known Roman amphitheatre. It is 444 feet long and 342 feet in width with a wall 6½ feet high surrounding the arena. The frescoes in stucco which covered the walls are now known to us only from copies in the Naples Museum. Thirty-five rows of seats, now almost entirely grown over with grass, accommodated about twenty thousand spectators. It was simple in design compared to the elaborate four-storied Colosseum with its massive concrete walls and movable platforms on which wild beasts and gladiators were raised through trap-doors.

## Building on a Grand Scale

THE Romans admired bigness and magnificence in their spectacles as well as in architecture. They were prodigal of labor and of money, constructing temples, arches and other monuments on a stupendous scale throughout a territory comprising nearly all of the then-known world. Concrete construction made available the unskilled labor of innumerable soldiers and captives, and saved centuries of time.

It is remarkable how solidly, even massively, the Romans built—the walls of the Pantheon at Rome being twenty feet thick and some of their roads were four feet thick, facts which indicate that they recognized the permanence of concrete construction and planned to leave behind them substantial records of the glory that was Rome's.



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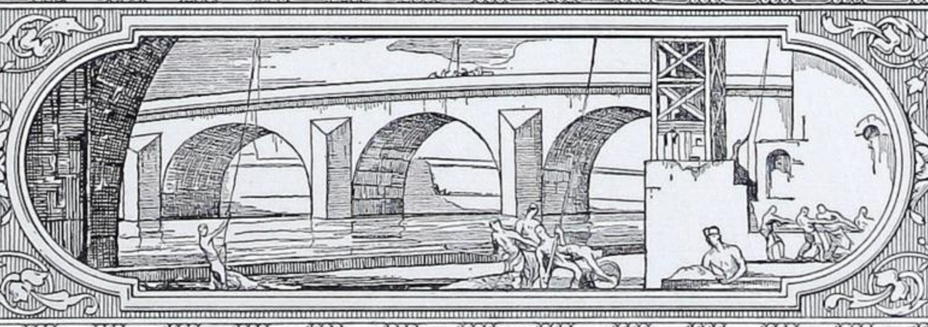


One of the great Hell Gate Towers of the New York Connecting Railroad Bridge over the East River, New York, the largest bridge of its kind in the world. Pennsylvania Cement was used in the construction of the two huge towers

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